0.1 e5 Run (E94-017)

The Neutron Magnetic Form Factor from Precision Measurements of the Ratio of Quasielastic Electron-Neutron to Electron-Proton Scattering in Deuterium

W. K. Brooks (Jefferson Lab), M. F. Vineyard (Union College)
and the CLAS Collaboration

0.1.1 Introduction

The e5 run of the CLAS Collaboration in Hall B consists of a single experiment, E94-017. The goal of this experiment is to determine the neutron magnetic form factor over a Q^2 range from 0.2 to 4.8 $(GeV/c)^2$ from precision measurements of the ratio of quasielastic electron-neutron to electron-proton scattering in deuterium.

Nucleon structure is one of the most fundamental issues in hadronic physics. Elastic electron scattering can be used to probe the electromagnetic structure of the nucleon. The differential cross section for elastic electron-nucleon scattering in the one-photon-exchange approximation is given by the Rosenbluth formula [Ro50] in which the nucleon structure information is contained in the Sachs electromagnetic form factors, G_E and G_M. These form factors provide information on the distributions of charge and magnetization current within the nucleon and are used for comparison between experiment and theoretical models of nucleon structure.

Until recently, the electromagnetic form factors for the proton have been determined experimentally from elastic ep scattering using the Rosenbluth separation technique [Ro50]. The magnetic form factor of the proton, G_M^p, appeared to be rather well determined over the range $0 < Q^2 < 30$ $(GeV/c)^2$, while the electric form factor, G_E^p, was determined with much less precision, particularly at high Q^2 where the cross section is dominated by G_M^p [Bo95]. These results indicated that the ratio $\mu_p G_E^p/G_M^p \simeq 1$, where $\mu_p = 2.79$ is the magnetic moment of the proton.

Recent measurements of $\mu_p G_E^p/G_M^p$ in Hall A at Jefferson Lab using a polarization transfer technique have shown that the form factor ratio decreases significantly from unity above $Q^2 = 1$ $(GeV/c)^2$ [Jo00, Ga01]. These results have led to intense theoretical activity [Bl00, De00, Ca00, Mi02] and a reanalysis of most of the world *ep* elastic cross section data using these new data as a constraint [Br02].

The neutron form factors have been determined with much less precision than those of the proton [Bo95]. Until the last decade most of the neutron form factor data came from analyses of inclusive quasielastic electron scattering from deuterium that introduce a number of significant systematic errors. More recently progress has been made in measurements [Ma93, Br95, An94, An98] of the neutron magnetic form factor, G_M^n, at low Q^2 values by measuring the ratio of quasielastic electron-neutron to electron-proton scattering in deuterium, a method in which many of the systematic uncertainties cancel. However, there are discrepancies among these measurements. Recently, measurements [Xu00] of inclusive quasielastic scattering of polarized electrons off a polarized ^3He target were performed in Hall A at Jefferson Lab and used to extract G_M^n at $Q^2 = 0.1$ and 0.2 $(GeV/c)^2$ with an experimental uncertainty of less than 2%. Also, significant progress is being made on the extraction of G_E^n from measurements of the $\overrightarrow{d}\,(\overrightarrow{e}, e'n)\,p$ [Zh01] and $d\,(\overrightarrow{e}, e'\overrightarrow{n})\,p$ [Ma93] reactions in Hall C at Jefferson Lab.

In this experiment, precise measurements of the ratio of quasielastic electron-neutron to electron-proton scattering in deuterium have been made over a broad range in Q^2 with the CLAS. The neutron magnetic form factor will be extracted from this ratio with the use of the more accurately known proton form factors. Data were taken simultaneously on separated hydrogen and deuterium targets. The $e + p \to e' + n + \pi^+$ reaction on the hydrogen target is used to measure the neutron detection efficiency. The data from electron-proton and electron-neutron scattering in deuterium are treated in an identical way insofar as possible. The use of this ratio technique, with the simultaneous calibration of the neutron detection efficiency, significantly reduces or eliminates many of the systematic errors associated with inclusive quasielastic scattering from deuterium. The results of this experiment will provide a significant improvement in our knowledge of the neutron magnetic form factor over the Q^2 coverage of existing measurements, and will extend the range to 4.8 $(GeV/c)^2$. In addition to providing accurate information on the magnetic structure of the neutron, these data will be important for the extraction of the electric form factor of the neutron from measurements of polarization observables which determine a linear combination of the electric and magnetic form factors (see for example Refs. [Zh01, Ma93]) and will allow a more accurate extraction of the strange quark form factor [An99].

0.1.2 Experiment Status

Data for E94-017 were collected during the e5 run in April and May of 2000 with the CLAS detector in Hall B at Jefferson Lab and are currently being analyzed. Approximately 2.3 billion triggers were acquired, about half at an electron beam energy of 2.6 GeV and half at 4.2 GeV. The low beam energy data were divided into two-thirds normal torus polarity and one-third reversed torus polarity. The reversed torus polarity data were taken to reach the lowest possible limit in Q^2. There is considerable overlap in Q^2 between the data taken at the two beam energies that provide important systematic cross-checks.

Shown in Figure 1 is a Q^2 distribution for quasielastic events in which a nucleon is detected from the deuterium target for an incident electron energy of 4.2 GeV. This spectrum represents less than 7% of the 4.2-GeV data set and shows that a large range in Q^2 is covered with good statistics for the reaction of interest. The lower Q^2 range is covered by the 2.6-GeV data set with a significant overlap with the 4.2-GeV data.

0.1.3 Expected Results

The data from the e5 run will provide the magnetic form factor of the neutron over the Q^2 range from 0.2 to 4.8 $(GeV/c)^2$, with uncertainties of a few percent over most of the range, with many systematic cross-checks. These measurements should eclipse and extend the entire world's data for this fundamental quantity. We anticipate having some preliminary results for G_M^n in early 2003. In addition, there are a number of other interesting physics quantities which will be extracted from this data set.

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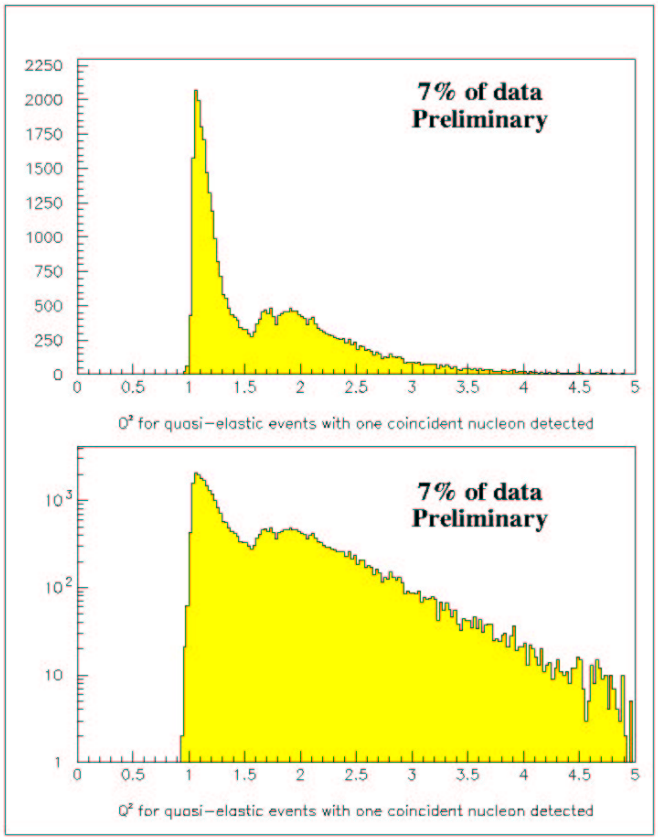

Figure 1: Q^2 distribution for quasielastic events in which a nucleon is detected from the deuterium target for an incident electron energy of 4.2 GeV. This spectrum represents less than 7% of the 4.2-GeV data set.